Spatial Determinants of Urban Growth in Chinese Cities: A Case Study of Dongguan

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Introduction

By 2012, 51.3% of the population in China lived in the urban areas. This is the first time that more people live in cities than in the rural areas in China. The unprecedented urbanization in Chinese cities are accompanied with the increased burden on urban environment due to the loss of agricultural land, growing energy consumption and aggregating air and water pollution. Timely and accurate assessment of the urban growth and underlying factors is critical for effective urban planning and management in Chinese cities.

Research Objectives

Through a case study of the urban growth in Dongguan, a rapidly industrializing city in China, this project aimed to achieve two research objectives. First, using landscape ecology and the concentric analysis methods, we provide a quantitative assessment of urban land conversion in Dongguan. Second, employing a spatial logistic regression, we incorporate the spatially non-stationary process in modeling the determinants of urban growth in Dongguan.

Study Area and Data

Dongguan is located in South China and is near Hong Kong; the urban growth in this city is greatly driven by the rural industrialization and the inflow of foreign investment from Hong Kong and Taiwan (Fig. 1). We collected the land use data from the Landsat TM images (30m*30m) in 1988, 1993, 1999 and 2006. The satellite images were classified into six land use types including built-up area, development zones or construction sites, water or wet land, forest, farmland and orchard (Fig.2).

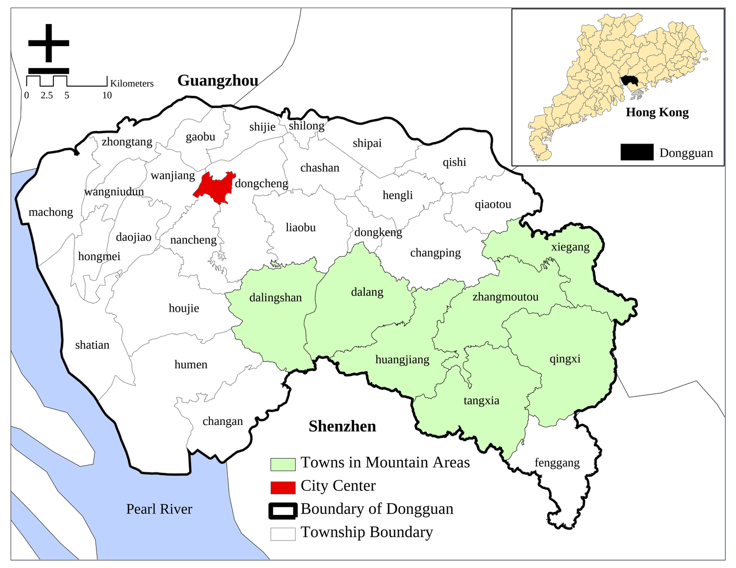

Fig. 1. Location and spatial structure of Dongguan

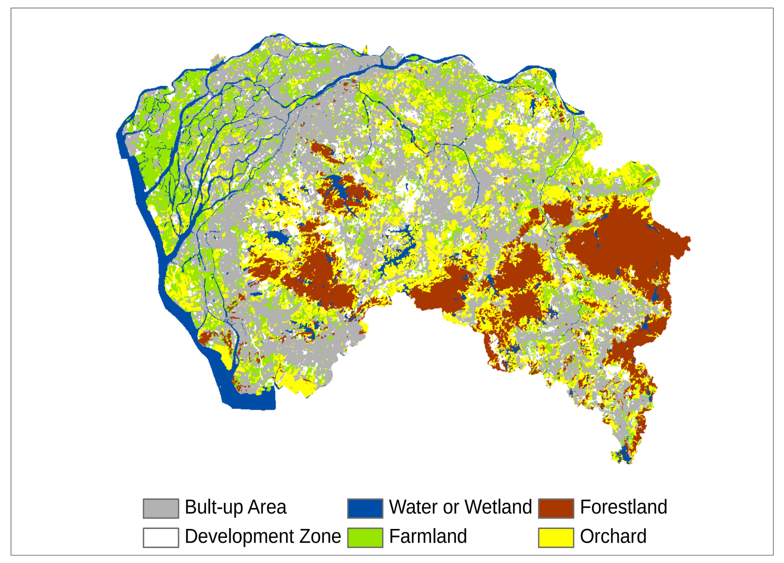

Fig. 2. Land Use in Dongguan, 2006

We randomly selected 17,552 pixels, which consisted of 8776 points with rural-urban land conversion (coded 1) and 8776 points without urban land conversion (coded 0) between 1988 and 2006. The selection of explanatory variables was guided by the theory of economic geography and urban economics. They included proximity to transportation network, socioeconomic factors and agglomeration economies, and physical and ecological conditions (Table 1).

Table 1. Dependent and Explanatory Variables

Variables	Types	Descriptions
Dependent variable		
Change	Dummy	Land use conversion from non-urban to urban between 1988 and 2006
Explanatory variable		
Proximity to transportation network		
Dis2Hwy	Continuous	Distance to highway
Dis2Rail	Continuous	Distance to railway
Dis2Road	Continuous	Distance to roads
Physical and ecological conditions		
DenFarm	Continuous	Density of farm land
DenOrchard	Continuous	Density of orchard land
DenForest	Continuous	Density of forest
DenWater	Continuous	Density of water land
Slope	Continuous	Slope of sampled pixels measured by degree
Socioeconomic factors and agglomeration economies		
Dis2CBD	Continuous	Distance to city center
Dis2TC	Continuous	Distance to township center
DenDevZone	Continuous	Density of development zones/construction sites
DenUrban	Continuous	Density of built-up area

Methods

1. Urban growth type and concentric analysis

The newly developed urban patches were classified into three growth types: infill growth, spontaneous growth, and edge growth. The concentric analysis was used to distinguish between the monocentric form and polycentric form of urban growth.

Infill growth | Spontaneous growth | Edge Growth | Concentric Analysis (2km)

2. Logistic regression and spatial expansion

In the orthodoxy logistic regression (Eq. 1), the regression coefficients β_i are spatially constant or stationary. We expanded the regression coefficients β_i using a cubic function of spatial coordinates (μ_k, v_k) (Eq. 2). Therefore, the model allows the regression coefficients to be specific to each location (μ_k, v_k) .

$$\text{logit}(Y) = \beta_0 + \sum_{i=1}^{n} \beta_i \ x_i \qquad (1)$$

$$\begin{aligned}\beta_i^k = (&\gamma_i^0 + \gamma_i^1\mu_k + \gamma_i^2\mu_k^2 + \gamma_i^3\mu_k^3 + \gamma_i^4 v_k + \gamma_i^5\mu_k v_k + \gamma_i^6\mu_k^2 v_k + \gamma_i^7\mu_k^3 v_k + \gamma_i^8 v_k^2 \\ &+ \gamma_i^9\mu_k v_k^2 + \gamma_i^{10}\mu_k^2 v_k^2 + \gamma_i^{11}\mu_k^2 v_k^2 + \gamma_i^{12} v_k^3 + \gamma_i^{13}\mu_k v_k^3 \\ &+ \gamma^{14}\mu_k^2 v_k^3 + \gamma^{15}\mu_k^3 v_k^3)\end{aligned} \qquad (2)$$

Results

1. The evolution of urban pattern in Dongguan, 1988-2006

The urban area in Dongguan increased by 1181% from 67 sq km in 1988 to 787 sq km in 2006. The urban growth in Dongguan showed a multi-center and township based pattern (Fig. 3). Urban sprawl dominated the growth type; the infill growth has surpassed the spontaneous growth since the mid 1990s, which is consistent with the theory of urban growth phases and the ‘‘diffusion-coalescence’’ model. (Fig. 4).

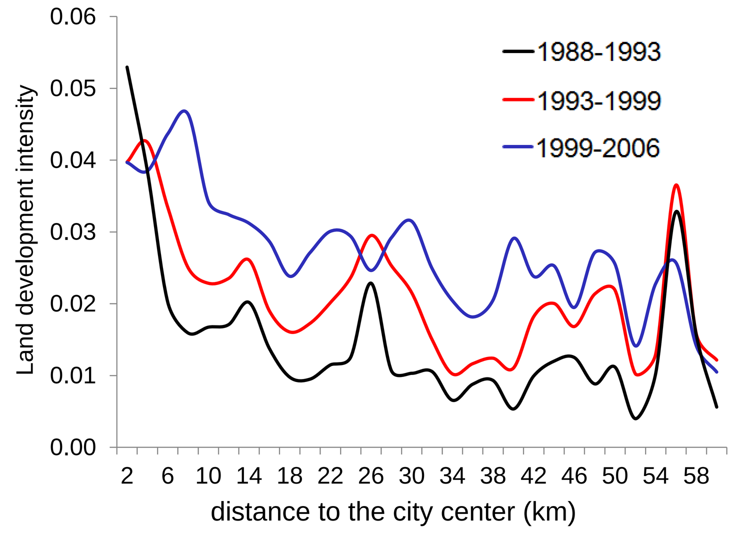

Fig. 3. Land development intensity and the distance to the city center

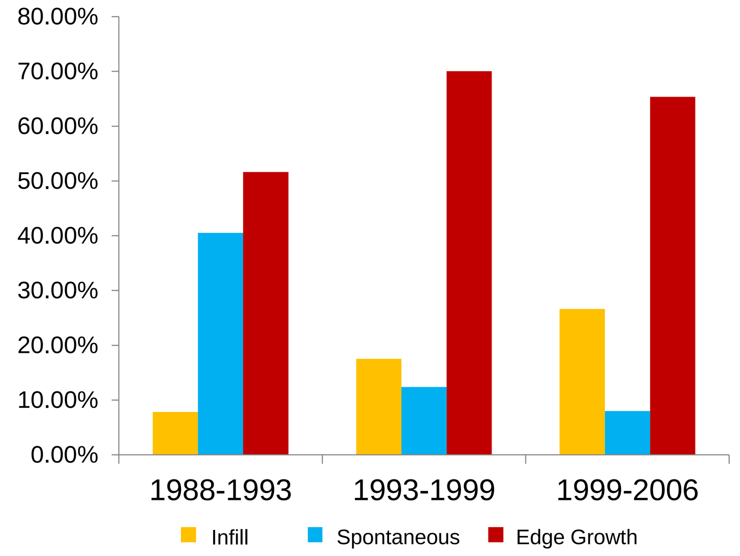

Fig. 4. Shares of different urban growth types

2. Non-spatial logistic regression

Results of non-spatial regression revealed that, first, urban growth was centered on township centers in Dongguan rather than the city center. Second, urban agglomeration economies and industrial development zones played an important role in urban growth. Third, urban growth was also sensitive to the proximity to the transportation network especially the highways and roads. Fourth, urban growth was constrained by the physical conditions such as slope, water bodies and forests. Fifth, urban growth was at the expense of the loss of agricultural land (Table 2).

Table 2. Results of non-spatial regression

Proximity to transportation Network	Coefficient	Physical & Ecological Conditions	Coefficient	Socioeconomic Factors & Agglomeration Economies	Coefficient
Dis2Roads	-0.198***	DenFarm	0.002***	Dis2TC	-0.129***
Dis2Hwy	-0.076***	DenOrchard	0.002***	Dis2CBD	0.015***
Dis2Rail	-	Slope	-0.011***	DenUrban	0.002***
		DenForest	-0.002***	DenDevZones	0.006***
		DenWater	-0.002***		
Observations	17552	ROC	0.766	-2 log Likelyhood	19649.7

Notes: * significant at 0.05 level ; ** significant at 0.01 level; *** significant at 0.001 level

3. Spatial Logistic Regression

The spatial logistic regression improved the non-spatial logistic regression with better overall goodness of fit, prediction accuracy and smaller spatially correlated errors measured by the Moran’s I index (Table 3).

Table 3 Comparison between non-spatial logistic regression and the logistic regression with spatially expanded coefficients

	Non-spatial Logistic regression	Logistic model with spatially expanded coefficients
-2*Log likelihood	19649.71	17962.94***
Pseudo R square	0.1924	0.2618
ROC	0.766	0.819
Moran's I of residuals	0.2112**	0.1234**

Notes: * significant at 0.05 level ; ** significant at 0.01 level; *** significant at 0.001 level

In comparison with the constant coefficients in the non-spatial logistic model, the values of coefficients derived from the spatial logistic model show significant spatial variations (Table 4)

Table 4. Summary of spatially varying coefficients

Variable	Mean	Std. Dev.	Min	Max	% positive	% negative
Dis2Hwy	0.0047	0.2422	-1.1611	0.7173	59.09	40.91
Dis2Rail	-0.0429	0.1391	-0.7023	0.3513	37.97	62.03
Dis2Road	-0.3512	0.3319	-1.0893	2.0436	8.58	91.42
DenFarm	0.0040	0.0024	-0.0060	0.0135	93.51	6.49
DenOrchard	0.0032	0.0030	-0.0052	0.0106	82.65	17.35
DenForest	-0.0044	0.0102	-0.0765	0.0049	30.21	69.79
DenWater	-0.0011	0.0035	-0.0180	0.0139	26.18	73.82
Slope	-0.0081	0.0163	-0.0445	0.0650	23.64	76.36
Dis2CBD	-0.0147	0.0592	-0.1553	0.1024	45.20	54.80
Dis2TC	-0.1066	0.1402	-0.5612	0.8374	17.24	82.76
DenDevZone	0.0080	0.0078	-0.0137	0.0531	88.38	11.62
DenUrban	0.0029	0.0042	-0.0099	0.0207	75.11	24.89

The resulting coefficient surfaces present more details about the local influence of explanatory variables on urban growth. For example, although the Dis2CBD had positive impact on urban land conversion in the non-spatial model, it had strong locally negative impact on the urban land development in the north of the city where a new CBD of Dongguan is being built (Fig 5).

In the non-spatial logistic model, urban growth was constrained by water bodies and forests. However, drawing upon the spatial logistic model, these effects were contingent upon local conditions and environment protection policies—in the northwestern and central portions, water bodies forests had danger of being converted into urban land (Fig. 6).

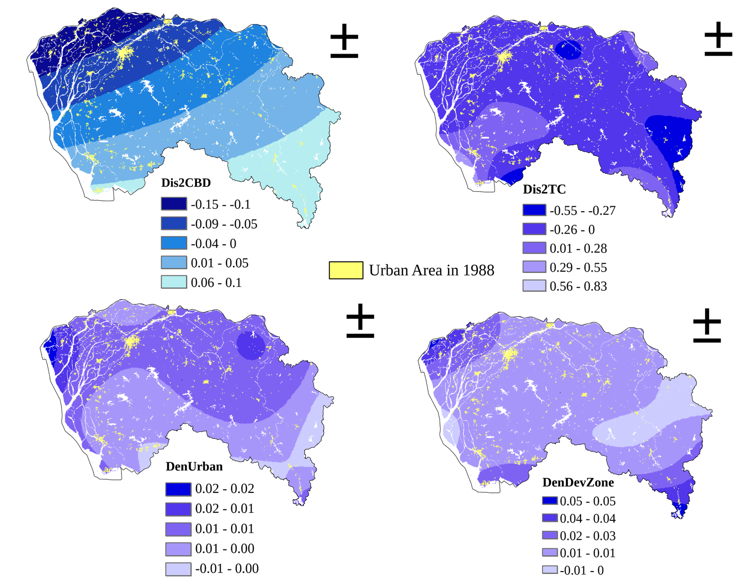

Fig. 5 Coefficient surfaces of socioeconomic factors

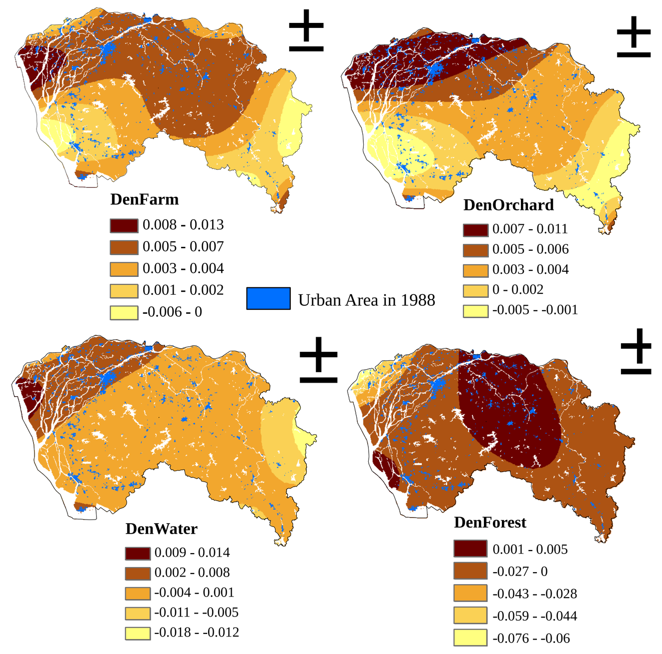

Fig. 6 Coefficient surfaces of physical and ecological conditions

Conclusions

The unique township-based urban growth in Dongguan demonstrates the diverse urban pattern in Chinese cities, while the process of urban expansion is consistent with the theoretical ‘‘diffusion-coalescence’’ model.

The urban planning and environment protection policies had played a role in mediating the unregulated urbanization in Dongguan since the late 1990s. However, their effects are limited and Dongguan still faces substantial environmental challenges arising from the urban expansion.

Urban growth is a spatially non-stationary process and spatial expansion model can provide an exploratory tool for urban planning and management.

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